

OCTS Cloud Threshold Analysis

B. A. Franz

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1. Introduction

Obviously we need to mask thick clouds in the OCTS processing, as the sensor can not see through them and thus we have no chance of properly correcting for their effects. In principal, the scattering contribution of optically thin clouds can be estimated and removed, but limitations of the sensor and the atmospheric correction scheme of MSL12 makes such corrections highly uncertain. In fact, MSL12 will treat such artifacts as thick aerosols, and assume a scattering phase function and effective altitude which may not be appropriate. The uncertainty introduced in treating cloud effects as aerosols will increase with optical thickness. The purpose of this analysis is to examine the trade-off between coverage loss and atmospheric correction uncertainty as the level of cloud screening is adjusted.

The cloud screening algorithm used by MSL12 is a simple threshold on the top-of-atmosphere (TOA) reflectance at 865 nm. The standard SeaWiFS threshold (referred to as the albedo) is 1.1%. The initial threshold for OCTS GAC evaluations was set to 0.9%. A lower threshold was used for OCTS because the global average aerosol optical thickness (AOT) retrievals at 865 nm were found to be lower than the equivalent SeaWiFS retrievals, suggesting that the 865 nm calibration of OCTS is low relative to SeaWiFS and hence clouds would appear less reflective. A recent processing run was performed with this albedo set to 1.0%, and the results of this test will be compared with those from an otherwise equivalent run where the albedo was set to 0.9%. The comparison will be done with the monthly global composite maps for Nov 1996 and May 1997.

In raising the cloud albedo threshold, we expect that the number of pixels containing valid retrievals will increase, thus yielding better global coverage. In addition, we expect that some number of monthly-averaged pixels will be completely unchanged, as there will be many locations where raising the cloud threshold will not increase the number of observations in a given bin. Finally, we expect to see a population of pixels which have been altered at some level, as these are cases where one or more additional observations were able to pass the cloud mask at the higher threshold level. These three populations will be examined independently, with the hope that we can increase overall coverage without significantly changing the results in the population of common pixels. The assumption in our evaluation is that if we raise the albedo threshold too high, we will include retrievals in the monthly averages which have significant atmospheric correction error, and that error would be manifest as a bias in the monthly averaged differences between common pixels of the high and low albedo cases.

2. Presentation of Results

Figures 1 through 6 show comparison images of monthly averaged oceanic and atmospheric optical properties retrieved from OCTS data using the two albedo thresholds. Figures 1 through 3 show November 1996 results for chlorophyll-a, AOT(865), and nLw(443). Figures 4 through 6 show the same products for the May 1997 monthly composite. A quick glance at these images will reveal that raising the albedo threshold has virtually no qualitative impact. A closer inspection would show that there are regions of increased coverage in the 1% threshold case, most notably in the high-latitude areas of the northern hemisphere and in the vicinity of the sub-solar point. These are areas with sparse coverage due to systematic masking by clouds or tilt operations, where a small increase in observations can have a significant impact.

The total increase in coverage is shown in Table 1. The higher albedo threshold resulted in an increase in the number of unmasked pixels of 3.4 and 4.2% for May and November, respectively. For chlorophyll retrievals, the mean and median of the global distribution changed by less than 0.005 mg m^{-3} for both months. The standard deviation of the distribution chlorophyll increased slightly for the higher albedo case in November, suggesting that the additional retrievals might be adding noise, but the standard deviation actually decreased for the May case, and in both months the change was less than 0.01 mg m^{-3} . The mean and median global aerosol optical thickness also increased slightly (less than 0.007) with increased albedo threshold.

Table 1: *Statistics on the global monthly composites, all pixels*

Month	Product	Albedo	# Pixels	Median	Mean	Std. Dev.
November	Chlor-a	0.9	3433056	0.129	0.218	0.636
November	Chlor-a	1.0	3576058	0.133	0.222	0.647
November	AOT(865)	0.9	3433056	0.105	0.108	0.040
November	AOT(865)	1.0	3576058	0.110	0.115	0.041
May	Chlor-a	0.9	3318891	0.124	0.319	0.911
May	Chlor-a	1.0	3433521	0.129	0.321	0.904
May	AOT(865)	0.9	3318891	0.095	0.099	0.034
May	AOT(865)	1.0	3433521	0.100	0.105	0.036

We can do a more direct comparison of the threshold effect if we limit the results to those pixels where we had retrievals for both cases, and then compute pixel-to-pixel differences. Table 2 shows the median, mean, and standard deviation of these differences for the global monthly composites. This difference distribution is dominated by pixels with identical retrievals for both albedo cases, so the median difference is very close to zero. The mean differences are all positive, indicating that raising the albedo threshold does result in a small positive bias in both chlorophyll-a and aerosol optical thickness. Still, the mean differences are quite small at less than 0.0036 mg m^{-3} for chlorophyll and less than 0.0065 for AOT.

Table 2: *Statistical differences for common pixels of the global monthly composites.*

Month	Product	Median	Mean	Std. Dev.
November	Chlor-a	0.0	0.0036	0.15
November	AOT(865)	0.0	0.0065	0.013
May	Chlor-a	0.0	0.0020	0.17
May	AOT(865)	0.005	0.0062	0.012

As noted earlier, the statistics in Table 2 are dominated by the zero-differences: those pixels for which the raising of the cloud threshold did not result in additional observations being included in the binned averages. If we eliminate these zero-difference pixels, which account for approximately one third of all retrieved pixels, we can see more directly what impact the additional observations had on the results. Table 3 shows the same statistics as Table 2, but considering only non-zero differences between common pixels.

Table 3: *Statistical differences for common pixels of the global monthly composites, excluding zero-difference pixels.*

Month	Product	Median	Mean	Std. Dev.
November	Chlor-a	0.0041	0.0063	0.20
November	AOT(865)	0.010	0.012	0.016
May	Chlor-a	0.0038	0.0034	0.23
May	AOT(865)	0.010	0.011	0.014

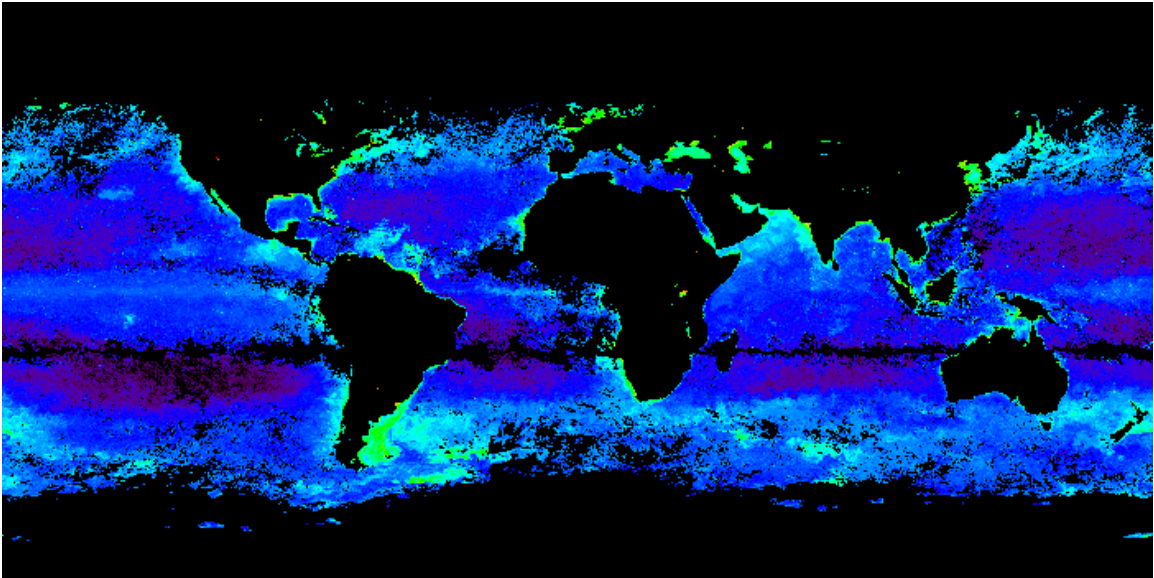
Even with this more stringent comparison, the differences are still quite small, but the bias is clearly toward slightly higher chlorophyll and AOT retrievals as the cloud albedo threshold is increased.

3. Recommendation

Is a 4% increase in coverage worth a 0.004 mg m^{-3} bias in the Chlorophyll retrievals? In reality, our uncertainty on chlorophyll is likely far greater than ± 0.004 , so the effect is lost in the noise. However, two test cases make for a weak conclusion. To best determine the appropriate cloud threshold level, it would be helpful to repeat this study using a series of thresholds, as such a test might show that there is a level at which the bias begins to increase rapidly. In the absence of this more detailed analysis, I recommend setting the cloud albedo to 1% for all subsequent processing.

Figure 1: *OCTS Monthly Averaged Global Chlorophyll, November 1996.*

a. *Cloud Albedo = 0.9%*



b. *Cloud Albedo = 1.0%*

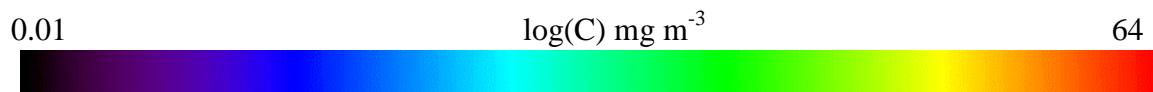
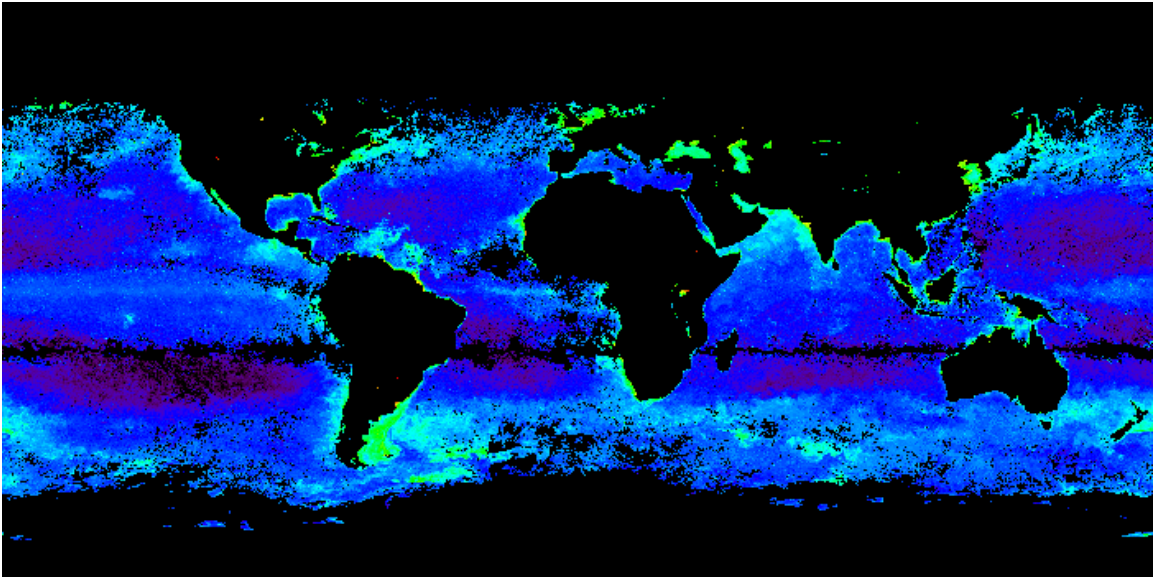
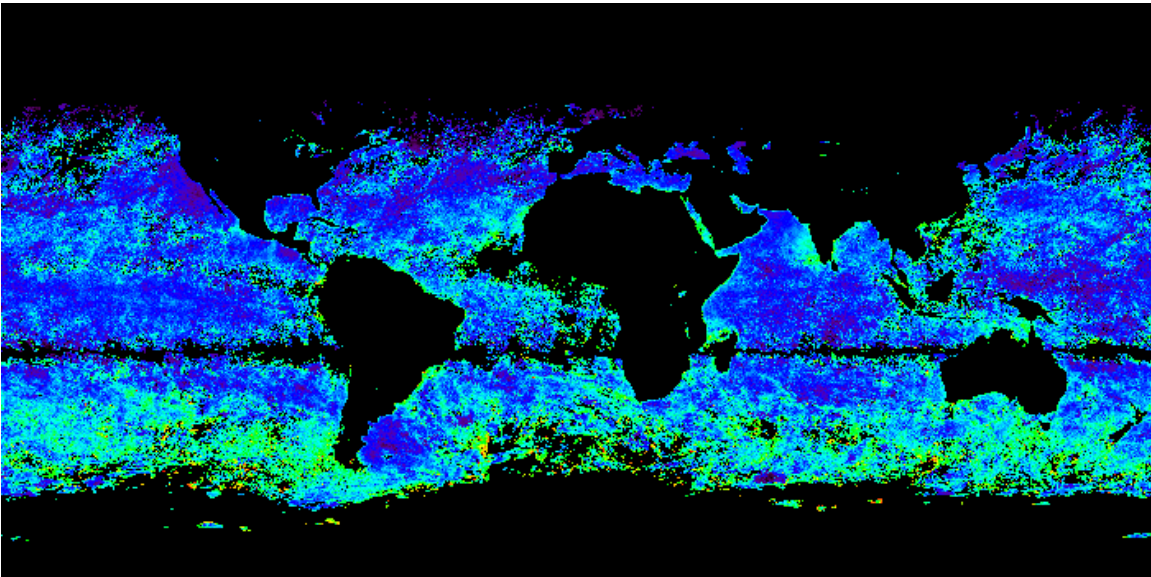


Figure 2: OCTS Monthly Averaged Global AOT(865), November 1996.

a. Cloud Albedo = 0.9%



b. Cloud Albedo = 1.0%

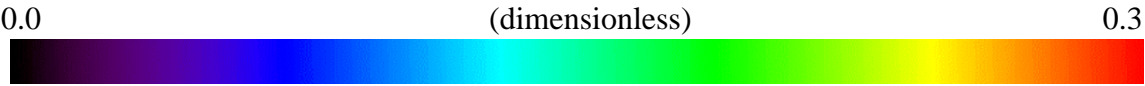
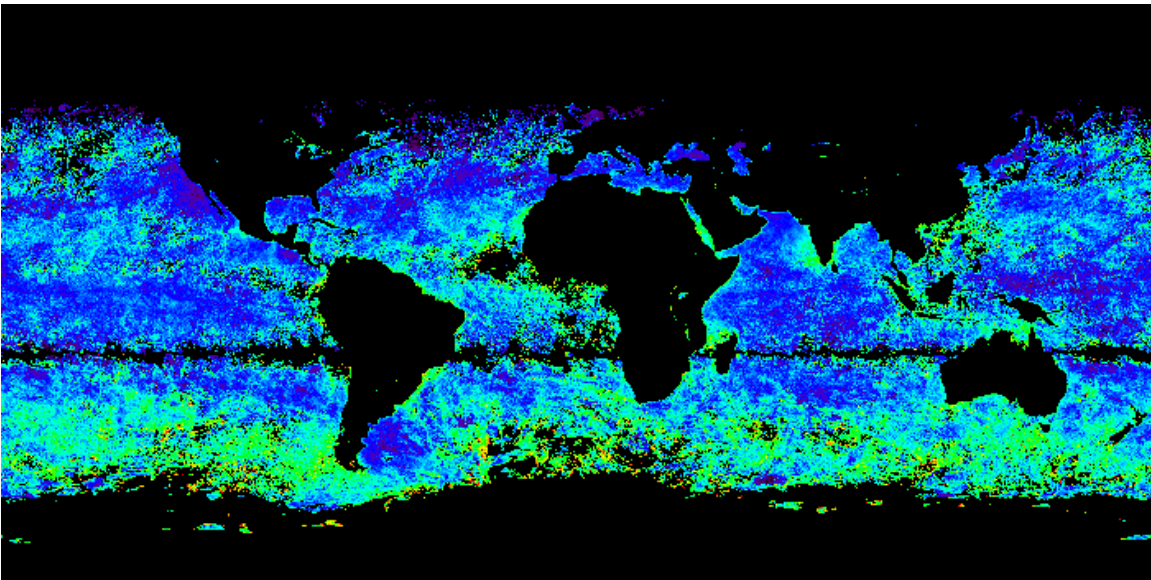
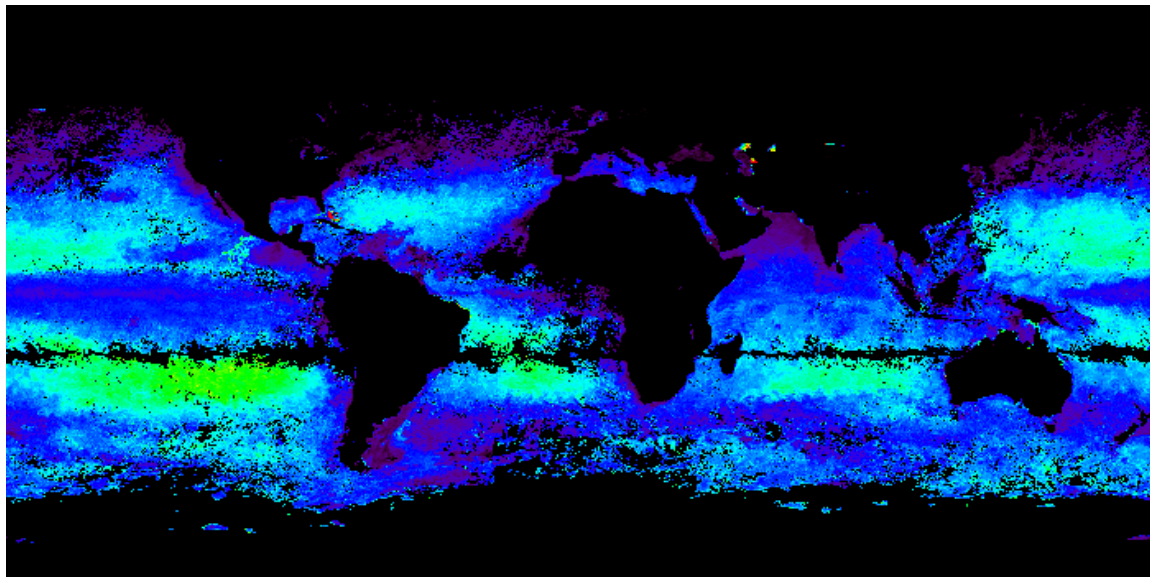


Figure 3: *OCTS Monthly Averaged Global $nLw(443)$, November 1996.*

a. *Cloud Albedo = 0.9%*



b. *Cloud Albedo = 1.0%*

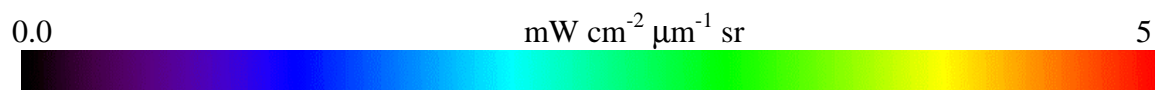
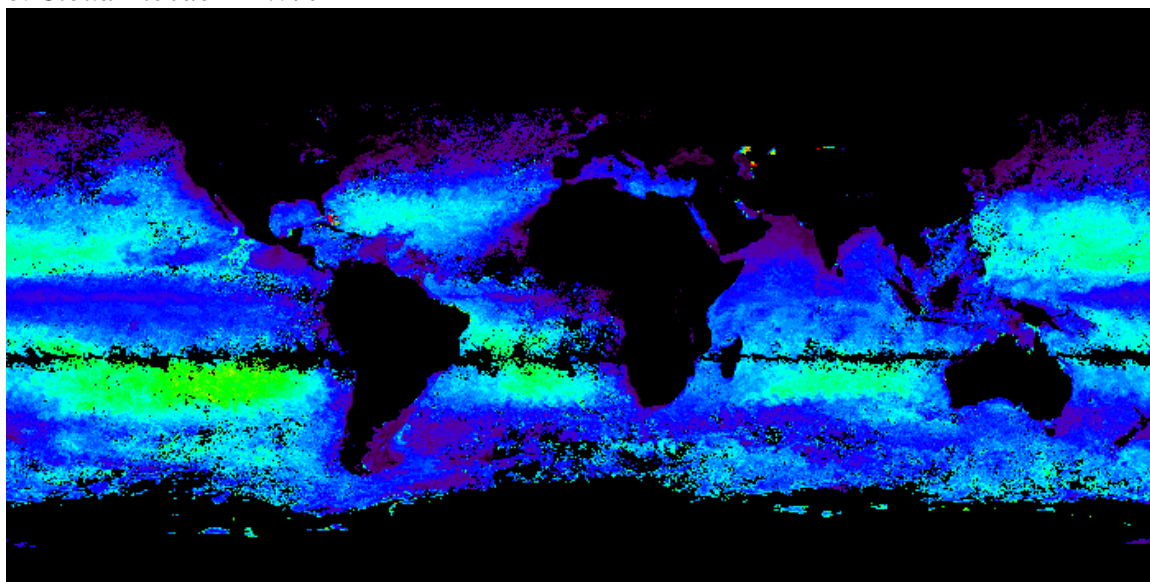
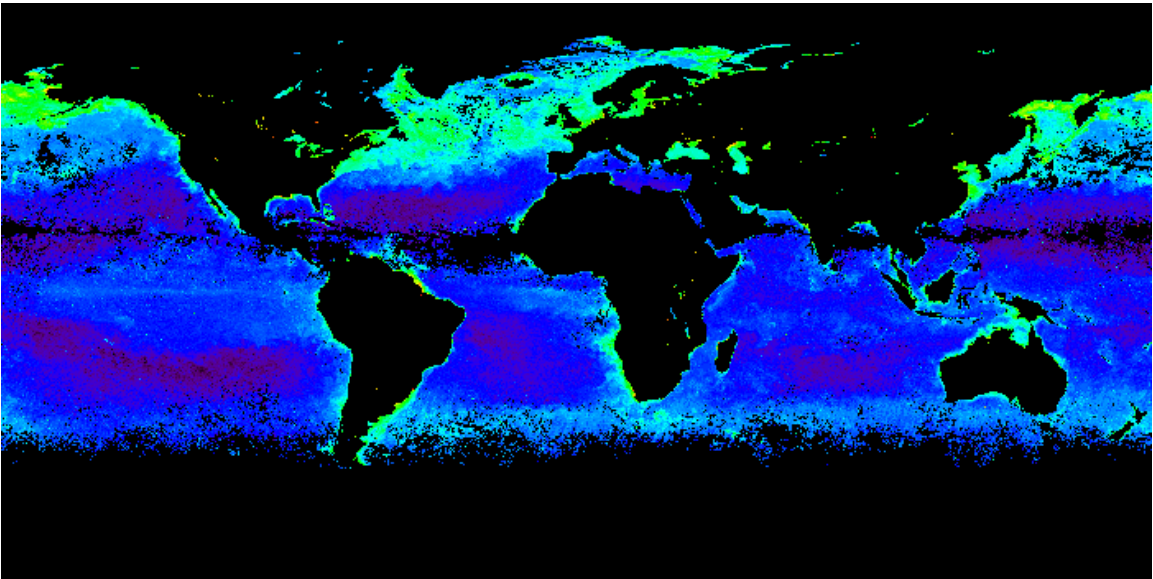


Figure 4: *OCTS Monthly Averaged Global Chlorophyll, May 1997.*

a. *Cloud Albedo = 0.9%*



b. *Cloud Albedo = 1.0%*

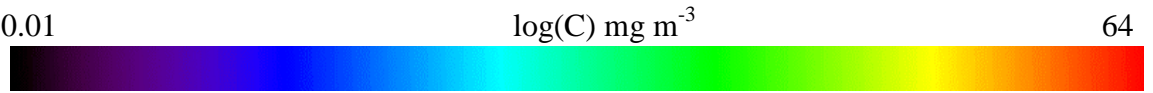
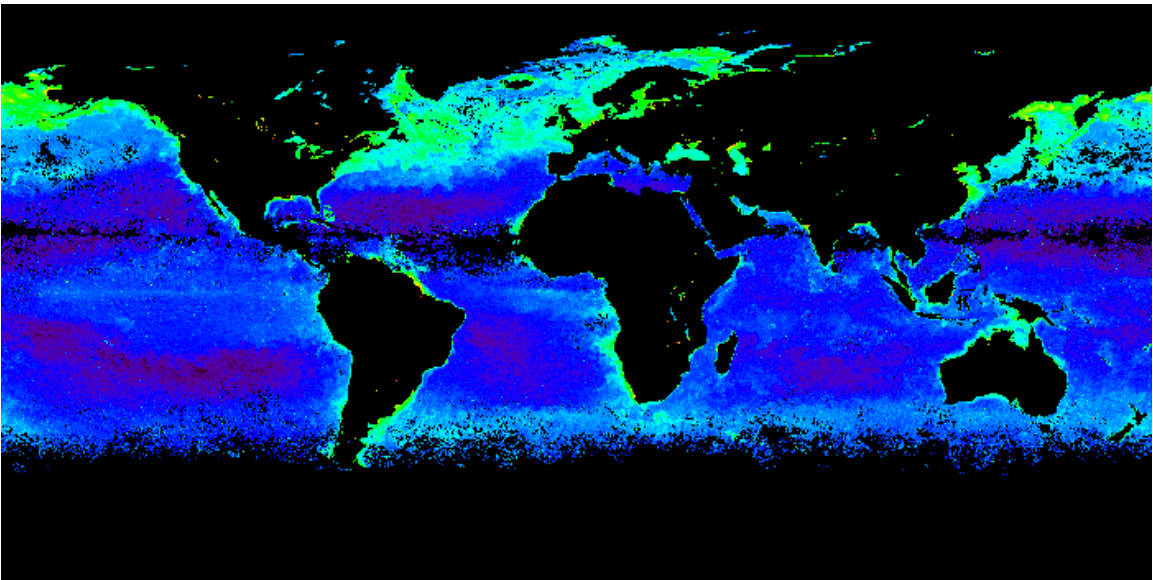
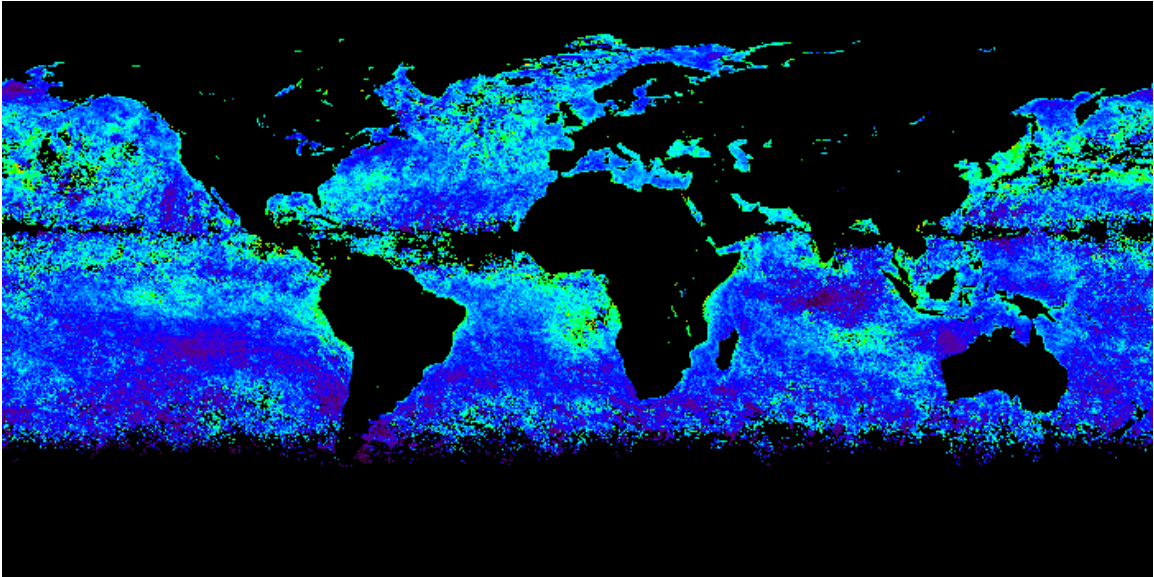


Figure 5: *OCTS Monthly Averaged Global AOT(865), May 1997.*

a. *Cloud Albedo = 0.9%*



b. *Cloud Albedo = 1.0%*

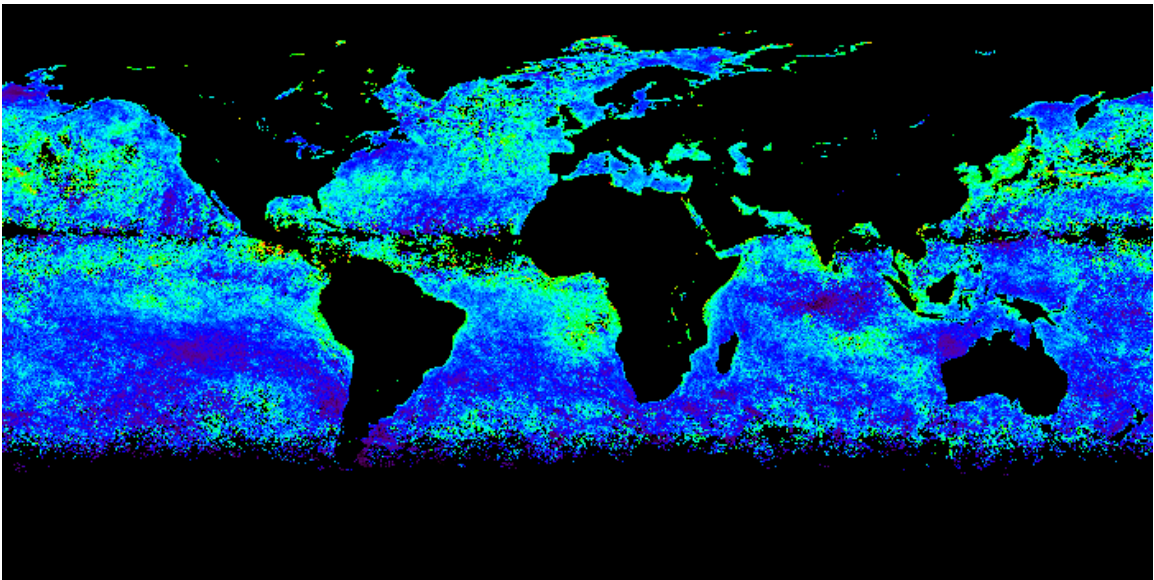
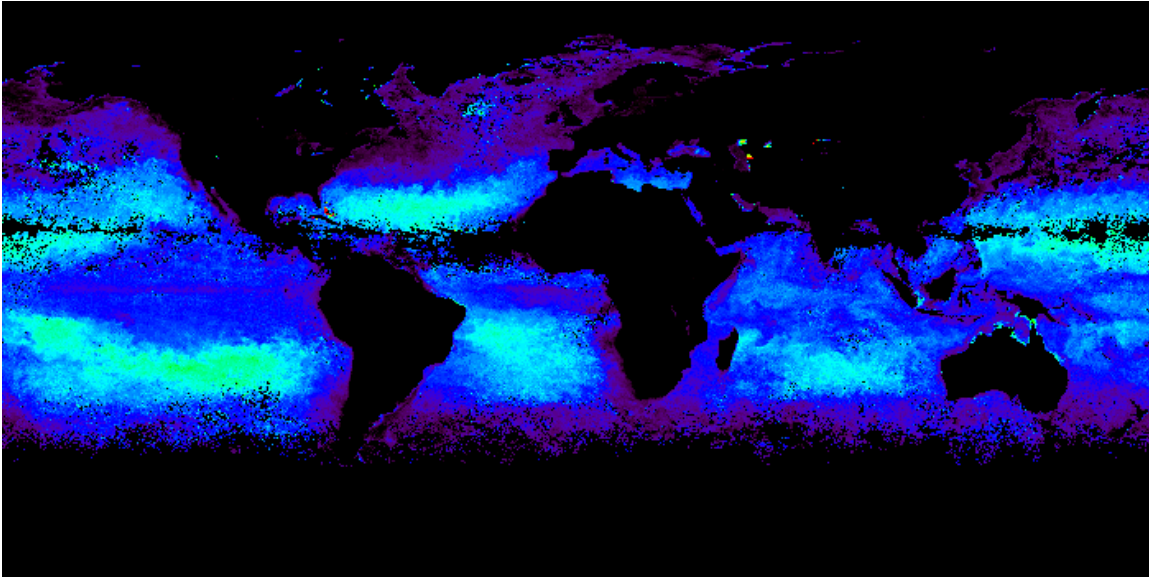


Figure 6: *OCTS Monthly Averaged Global nLw(443), May 1997.*

a. *Cloud Albedo = 0.9%*



b. *Cloud Albedo = 1.0%*

